



ELSEVIER

Contents lists available at ScienceDirect

## Theoretical Computer Science

www.elsevier.com/locate/tcs

Improved periodic data retrieval in asynchronous rings with a faulty host <sup>☆</sup>Evangelos Bampas <sup>a,\*,1</sup>, Nikos Leonardos <sup>b</sup>, Euripides Markou <sup>c,\*,2</sup>,  
Aris Pagourtzis <sup>d,3</sup>, Matoula Petrolia <sup>e</sup><sup>a</sup> LaBRI, Univ. Bordeaux, Talence, France<sup>b</sup> LIAFA, Univ. Paris Diderot, Paris, France<sup>c</sup> Department of Computer Science and Biomedical Informatics, University of Thessaly, Lamia, Greece<sup>d</sup> School of Electrical and Computer Engineering, National Technical University of Athens, Greece<sup>e</sup> LINA, University of Nantes, France

## ARTICLE INFO

## Article history:

Received 13 December 2014

Received in revised form 23 July 2015

Accepted 16 September 2015

Available online 26 September 2015

## Keywords:

Distributed algorithm

Mobile agent

Periodic data retrieval

Malicious host

Gray hole

Red hole

Unreliable whiteboard

## ABSTRACT

The exploration problem has been extensively studied in unsafe networks containing malicious hosts of a highly harmful nature, called *black holes*, which completely destroy mobile agents that visit them. In a recent work, Kráľovič and Miklík (SIROCCO 2010, LNCS 6058, pp. 157–167) [20] considered various types of malicious host behavior in the context of the *Periodic Data Retrieval* problem in asynchronous ring networks with exactly one malicious host. In this problem, a team of initially co-located agents must report data from all safe nodes of the network to the homebase, infinitely often. The malicious host can choose whether to kill visiting agents or allow them to pass through (gray hole). In another variation of the model, the malicious host can, in addition, alter its whiteboard contents in order to deceive visiting agents. The goal is to design a protocol for Periodic Data Retrieval using as few agents as possible.

In this paper, we present the first nontrivial lower bounds on the number of agents for Periodic Data Retrieval in asynchronous ring networks. Specifically, we show that at least 4 agents are needed when the malicious host is a gray hole, and at least 5 agents are needed when the malicious host whiteboard is unreliable. This improves the previous lower bound of 3 in both cases and answers an open question posed in the aforementioned paper.

On the positive side, we propose an optimal protocol for Periodic Data Retrieval in asynchronous rings with a gray hole, which solves the problem with only 4 agents. This improves the previous upper bound of 9 agents and settles the question of the optimal number of agents in the gray-hole case. Finally, we propose a protocol with 7 agents when the whiteboard of the malicious host is unreliable, significantly improving the previously

<sup>☆</sup> A preliminary version of this paper appeared in the proceedings of the 21st International Colloquium on Structural Information and Communication Complexity (SIROCCO 2014), July 2014, Hida Takayama, Japan, LNCS 8576, pp. 355–370.

\* Corresponding authors.

E-mail addresses: [evangelos.bampas@labri.fr](mailto:evangelos.bampas@labri.fr) (E. Bampas), [nikos.leonardos@gmail.com](mailto:nikos.leonardos@gmail.com) (N. Leonardos), [emarkou@ucg.gr](mailto:emarkou@ucg.gr) (E. Markou), [pagour@cs.ntua.gr](mailto:pagour@cs.ntua.gr) (A. Pagourtzis), [stamatina.petrolia@univ-nantes.fr](mailto:stamatina.petrolia@univ-nantes.fr) (M. Petrolia).

<sup>1</sup> This work was partially funded by the ANR project DISPLEXITY (ANR-11-BS02-014) and carried out in the frame of the “Investments for the future” programme IdEx Bordeaux–CPU (ANR-10-IDEX-03-02).

<sup>2</sup> This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) – Research Funding Program: THALIS-UOA (MIS 375891).

<sup>3</sup> This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) – Research Funding Program: THALIS-NTUA (MIS 379414).

known upper bound of 27 agents. Along the way, we set forth a detailed framework for studying networks with malicious hosts of varying capabilities.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

In distributed mobile computing, one of the main issues is the security of both the agents that explore a network and the hosts. Various methods of protecting mobile agents against malicious nodes as well as of protecting hosts against harmful agents have been proposed (see, e.g., [19] and references therein).

In particular, the exploration problem has been extensively studied in unsafe networks which contain malicious hosts of a highly harmful nature, called *black holes*. A black hole is a node which contains a stationary process destroying all mobile agents visiting that node, without leaving any trace. In the *Black Hole Search* problem (BHS in short) the goal for the agents is to locate the black hole within finite time. More specifically, at least one agent has to survive knowing all edges leading to the black hole. The problem has been introduced by Dobrev, Flocchini, Prencipe, and Santoro in [7,10]. Since any agent visiting a black hole vanishes without leaving any trace, the location of the black hole must be deduced by some communication mechanism employed by the agents. Four such mechanisms have been proposed in the literature: a) the *whiteboard* model [5,9,10,2,16] in which there is a whiteboard at each node of the network where the agents can leave messages, b) the *pure token* model [14,1] where the agents carry tokens which they can leave at nodes, c) the *enhanced token* model [6,11,23] in which the agents can leave tokens at nodes or edges, and d) the time-out mechanism (only for synchronous networks) in which one agent explores a new node and then, after a predetermined fixed time, informs another agent who waits at a safe node [21].

In an asynchronous network, the number of nodes of the network must be known to the agents, otherwise the problem is unsolvable [10]. If the graph topology is unknown, at least  $\Delta + 1$  agents are needed, where  $\Delta$  is the maximum node degree in the graph [9]. Furthermore, the network should be 2-connected. It is also not possible to answer the question of *whether* a black hole exists in the network. If the agents have a map of the network or at least a *sense of direction* [17,18] and can use whiteboards, then two agents with memory suffice to solve the problem. In asynchronous networks with dispersed agents (i.e., not initially located at the same node), the problem has been investigated for the ring topology [8,10] and for arbitrary networks [15,3] in the whiteboard model, while in the enhanced token model it has been studied for rings [12,13] and for some interconnected networks [23]. The problem has been also studied in synchronous networks. For a survey on BHS the reader is referred to [21].

As already mentioned, a black hole is a particular type of malicious host with a very simple behavior: killing every agent instantly without leaving any trace. In reality, a host may have many more ways to harm the agents: it may introduce fake agents, change the contents of the whiteboard, or even confuse agents by directing them to ports different from the requested ones.

In [20,22], Kráľovič and Miklík studied how the various capabilities of a malicious host affect the solvability of exploration problems in asynchronous networks with whiteboards. They first consider networks with a malicious host (called *gray hole*) which can at any time choose whether to behave as a black-hole or as a safe node. Since the malicious behavior may never appear, the agents might not be able, in certain cases, to decide the location of the malicious host. Hence, they introduce and study the so called *Periodic Data Retrieval* problem in which, on each safe node of the network, an infinite sequence of data is generated over time and these data have to be gathered in the homebase. The goal is to design a protocol for a team of initially co-located agents so that data from every safe node are reported to the homebase, infinitely often, minimizing the total number of agents used. One agent can solve the problem in networks without malicious hosts, where the problem reduces to the *Periodic Exploration* problem (e.g., see [4] and references therein) in which the goal is to minimize the number of moves between two consecutive visits of a node. When the malicious host is a black hole, the Periodic Data Retrieval and the Periodic Exploration problem are solved by the same number of agents. As observed in [20],  $n - 1$  agents are sufficient for solving the Periodic Data Retrieval problem in any 2-connected network of  $n$  nodes with one malicious host when the topology is known to the agents: each of the  $n - 1$  agents selects a different node of the network and periodically visits all other nodes. The authors show that two agents are not sufficient to solve the problem in a ring with a gray hole and they present a protocol which solves the problem using 9 agents. They also consider a second type of malicious host which behaves as a gray hole and, in addition, can alter the contents of its whiteboard; they show that 27 agents are sufficient to solve the Periodic Data Retrieval problem in a ring, under this type of malicious host.

*Our contribution.* In this paper, we study and refine the model of [20]. We present the first nontrivial lower bounds on the number of agents for Periodic Data Retrieval in asynchronous rings. Specifically, we show that at least 4 agents are needed when the malicious host is a gray hole, and at least 5 agents are needed when the malicious host whiteboard is unreliable. This improves the previous lower bound of 3 agents in both cases and answers an open question posed in [20]. On the positive side, we propose an optimal protocol for Periodic Data Retrieval in asynchronous rings with a gray hole, which solves the problem with only 4 agents. This improves the previous upper bound of 9 agents and settles the question of the optimal number of agents in the gray-hole case. Finally, we propose a protocol with 7 agents when the whiteboard of the

Download English Version:

<https://daneshyari.com/en/article/435625>

Download Persian Version:

<https://daneshyari.com/article/435625>

[Daneshyari.com](https://daneshyari.com)